

Pion-production target for Mu2e-II LDRD: update and status report

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Joint AF2/AF5/AF7/NF/RP Targetry Workshop

Fermilab

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Scope of LDRD (Laboratory-Driven R&D)

- Project for the **PIP-II era**: proton current on the Mu2e target could be higher by as much as a factor of 100 compared to the baseline Mu2e (**~x10 improvement** in the single event sensitivity).
- There is no Mu2e upgrade target concept close to satisfying the new requirements (for a **100-kW 800-MeV** proton beam). (We are aware of a 50-kW target prototype designed for MECO and PRISM at Irvine CA: MECO Production Target Development”, J.L.Popp, AIP V.721, p.321, 2003.)
- We are developing **a conceptual design using the MARS15 and G4beamline Monte-Carlo codes, and Mathematica** and are considering the most favorable aspects of the **granular, “conveyor”, and rotating cylindrical targets**. We are simulating the **overall target pion production performance and durability at beam induced pulsed energy deposition spikes**, thermal stress, radiation damage, muon stopping rates, residual activation and radiation loads.
- The project is aimed at the **design of the prototype** of the Mu2e-II pion-production target for the **100-kW 800-MeV** proton beam and its mechanical tests.

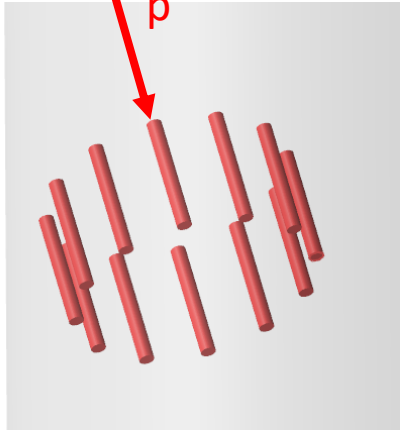
Deliverables:

- **Mid-2020 – Mid-2021**: the **plausible design** for the Mu2e-II target (**DONE**).
- **Mid-2021 – Mid-2022**: designed, printed, and tested. Conclusions regarding **feasibility** to be drawn.

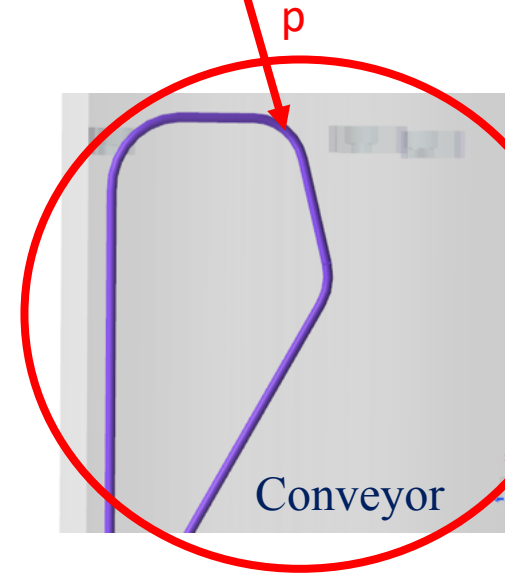
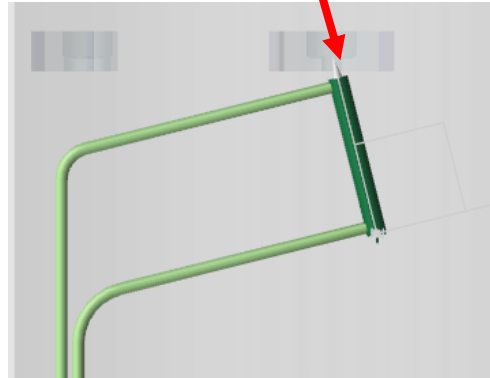
Prioritizing the designs under consideration: done

- Constraint: compatibility with the current HRS design (inner bore R=20-25) cm)

Rotating Elements



Fixed Granular Target



Pros: small space required; two-phase ammonia could be used for both cooling and moving elements inside conveyor; radiation damage can be distributed; **Cons:** technical complexity (prototyping needed)

Pros: radiation damage can be distributed over many rods
Cons: its hardware would require a significant space inside the bore (complicates cooling and muon flow)

Pros: small space required
Cons: peak DPA (MARS15) >300/yr; gas cooling cannot be performed efficiently

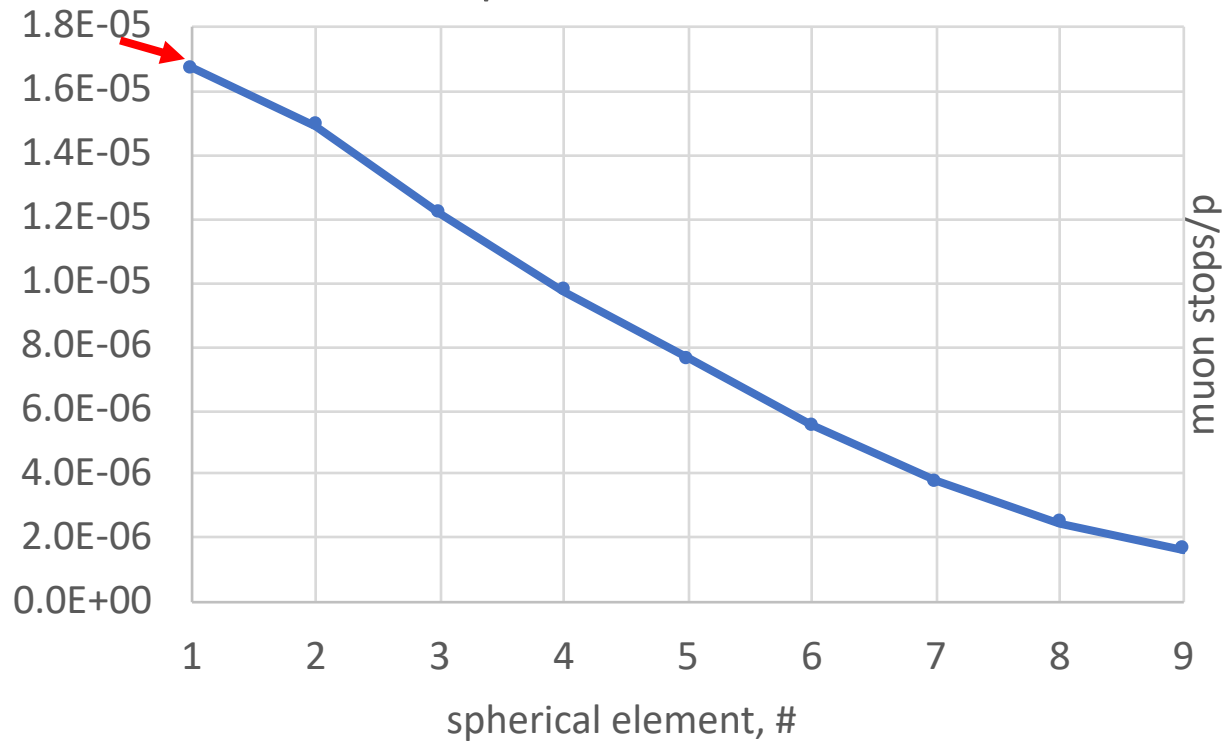
Target will be placed in the inner bore of Heat and Radiation Shield



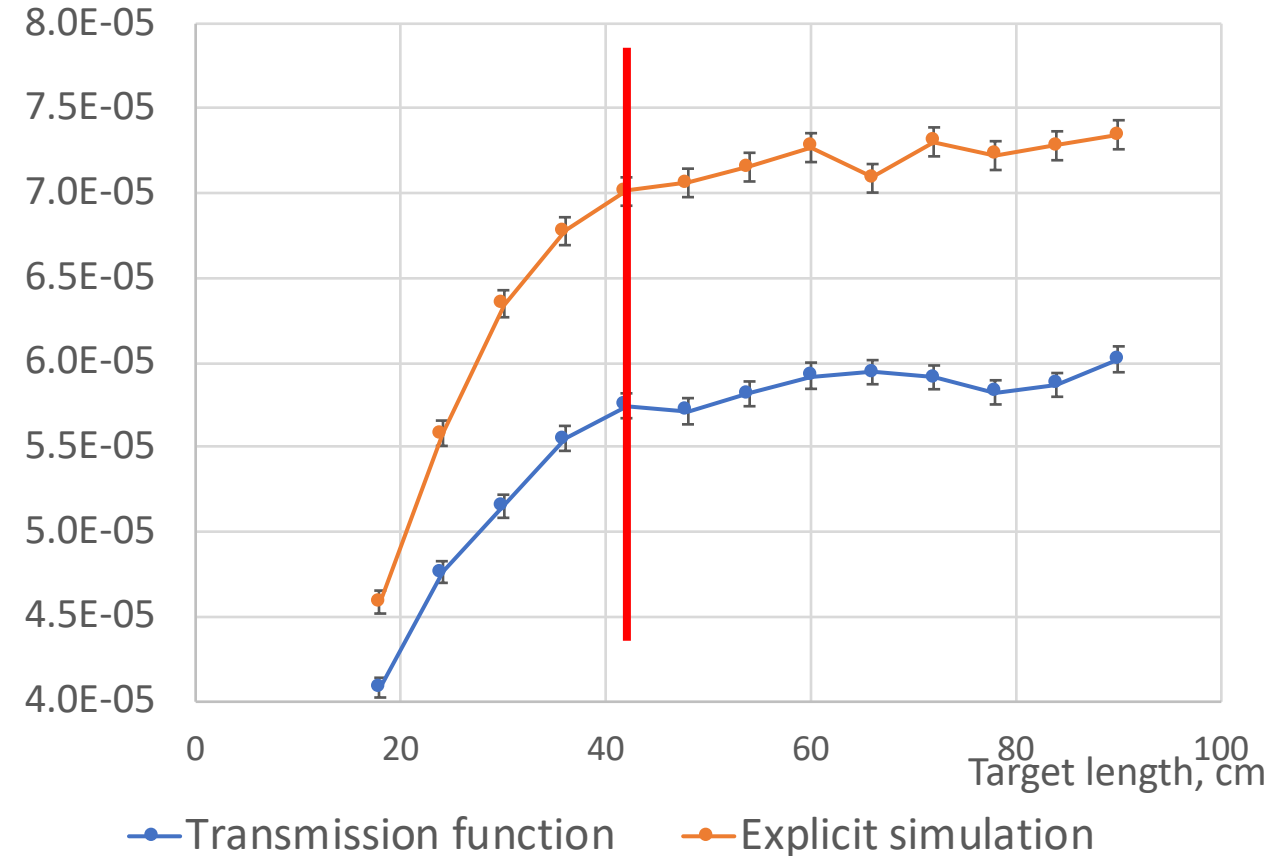
Interaction zone length and DPA

min balls required (DPA) = 150/yr DPA limit assumed ≤ 10

DPA in position/sec

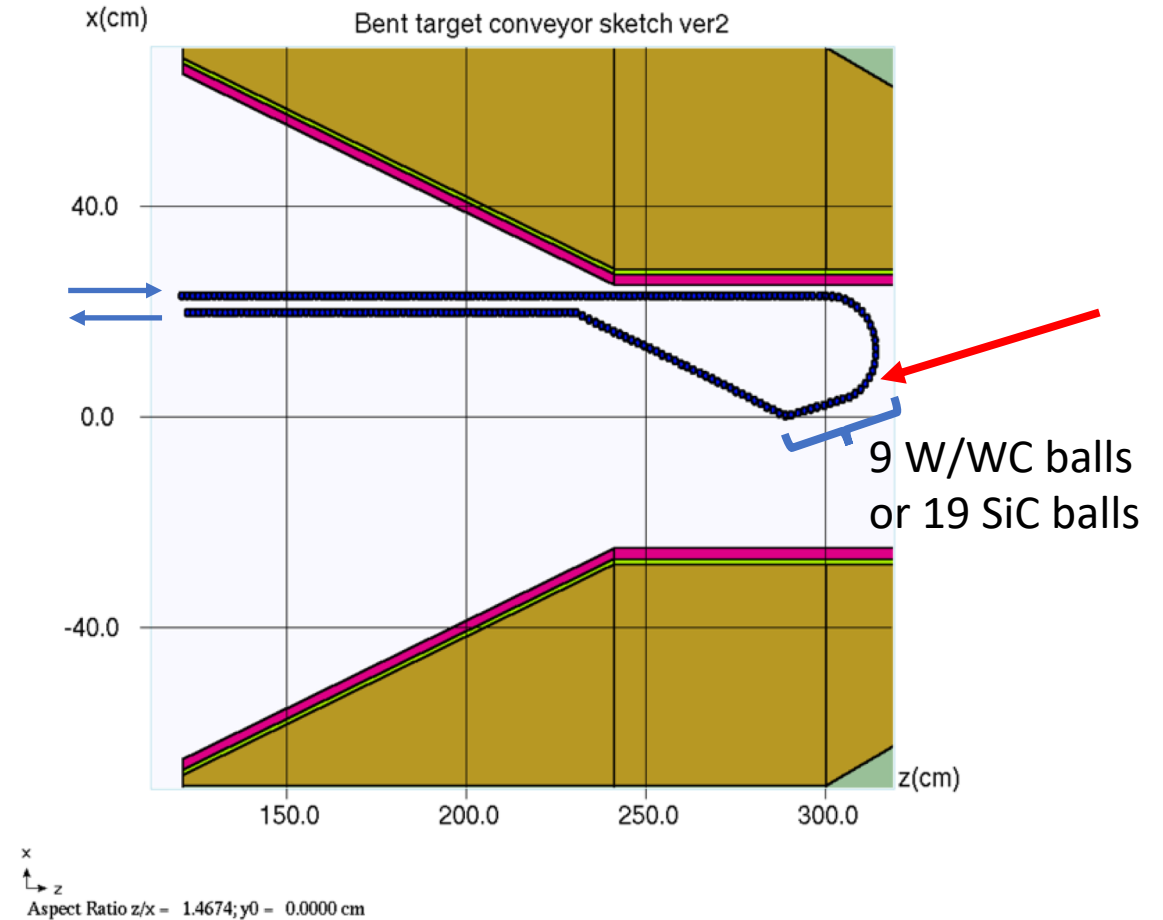
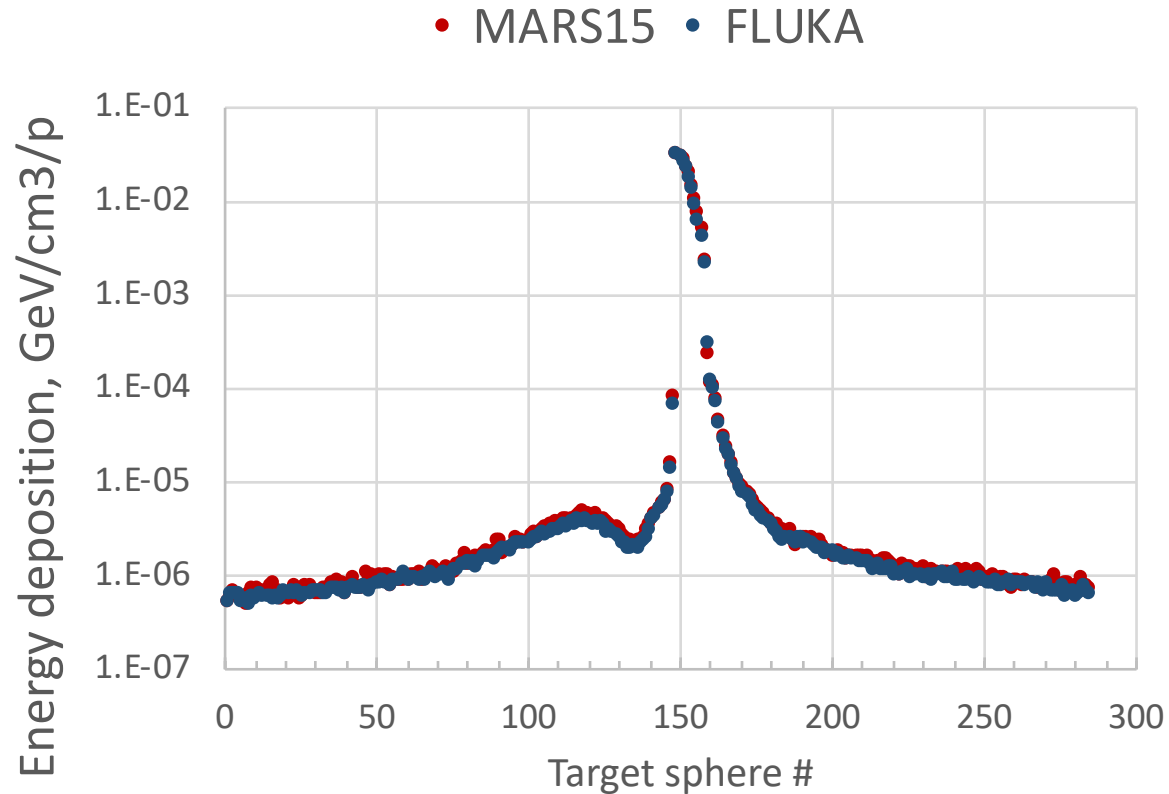


Carbon target length optimization by muon stops



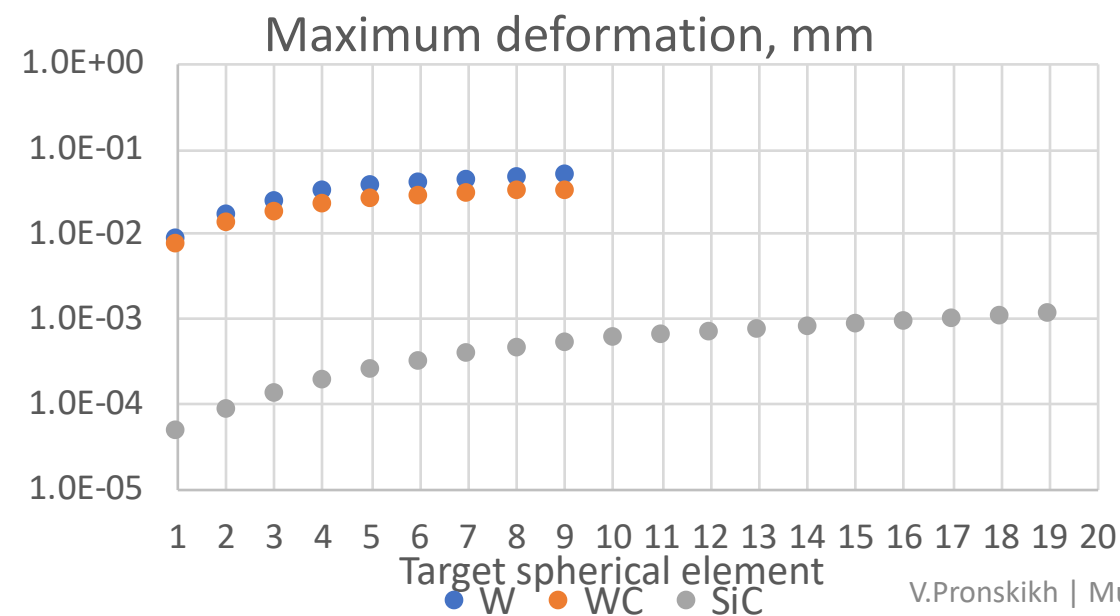
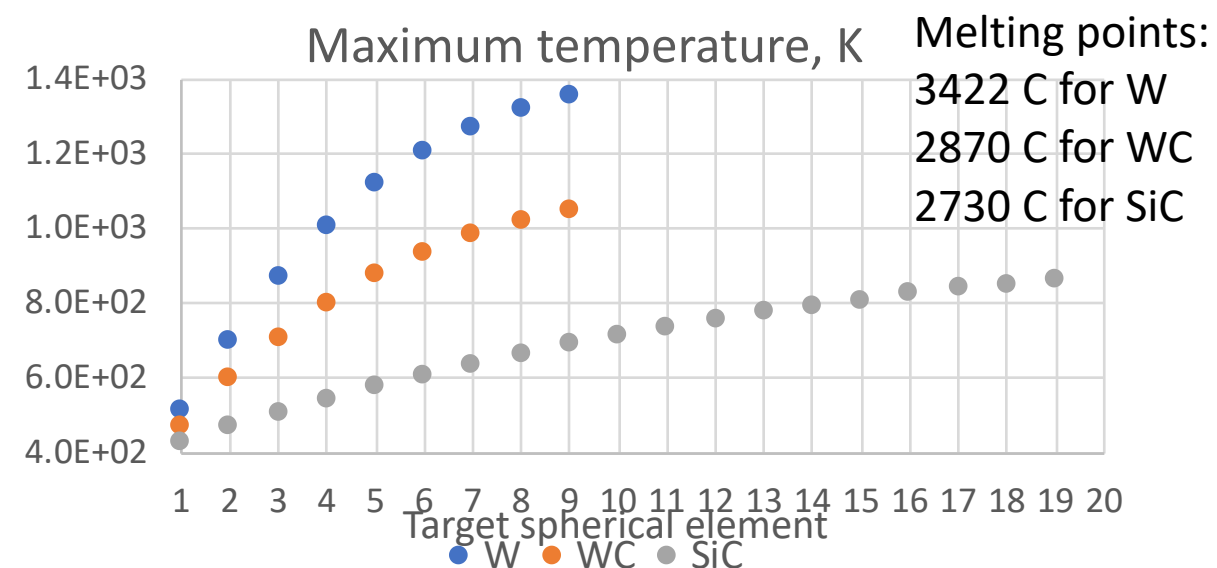
Based on muon stopping rate studies with MARS15 and G4beamline optimal target lengths were determined to be: 28 balls (C target), 9 balls (W and WC targets), 19 balls (SiC); MoGRCF was studied. Agreement between transmission and explicit allows saving computation time.

Energy deposition for a W target



- MARS15/FLUKA data agreement is better than 20% for energy deposition (FLUKA: Stefan Mueller).
- Total $E_{\text{dep}} = 31.8 \text{ kW}$; peak DPA (Nordlund) = 330 DPA/yr;
- Motion speed of spherical elements in conveyor is 10 cm/sec, DPA limit assumed ≤ 10
- (1.35 sec for an element to pass the beam). **More spherical elements are required by thermal analysis**

Conservative thermal and mechanical analyses: done



	Tungsten/WC	Lower-density bent (Carbon)
Rotated	Requires large hardware device inside HRS	Too large to fit in HRS
Fixed granular	DPA is too high	DPA is high; lower pion production
Conveyor	Thermal and mechanical analyses are ongoing; currently looks feasible	Lower pion production; thermal analysis is ongoing; currently looks feasible

Prototyping: started

Statement of work for Euclid Techlabs:

Deliverables:

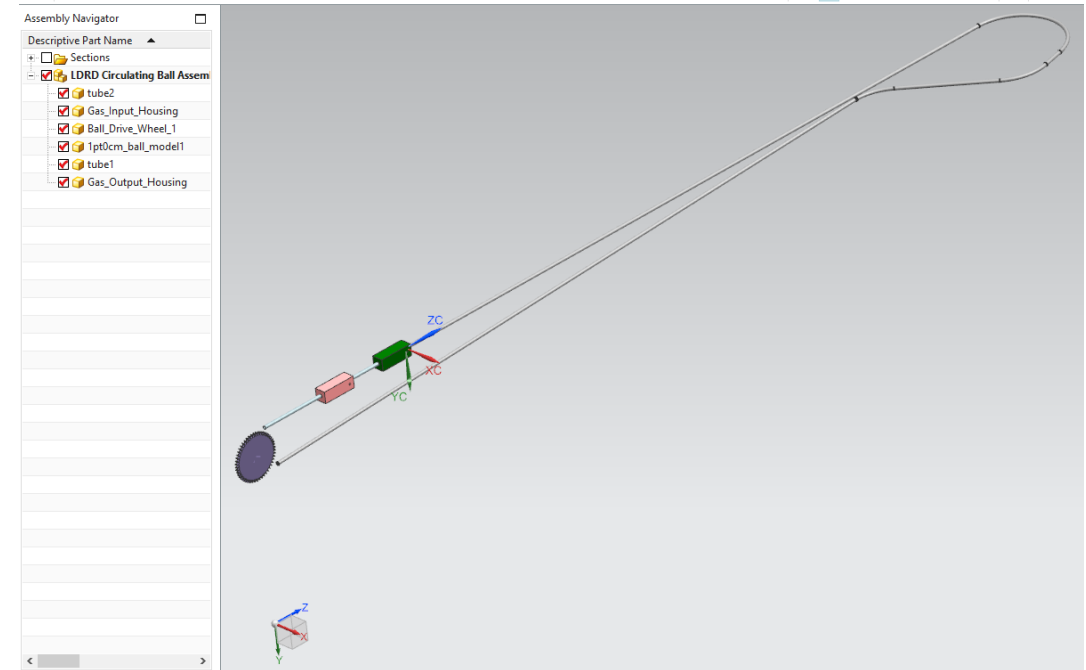
- 1) A physical model of a sphere circulation system, in which spheres with dimensions described above circulate at the speed mentioned above, using an optimal mechanism to be researched and discussed during the work between the company and the Fermilab team. The system includes the necessary machining and welding work to integrate the circulation tubing, connectors, etc., and the mechanism to contain the sphere driving apparatus. This model does **not** include the gas (such as compressed air) cooling system.
- 2) Any CAD models, **if developed and used** to build the physical model in (1). The CAD models can be delivered in their native file formats, such as SolidWorks files, or converted to STEP files. (Optional)
- 3) Summary report for discussions (between the company and the Fermilab team), problems identified, and experience gained during the execution of (1) and (2).

Delivery date: **12 weeks ARO, or 11/30/2021, whichever is later.**

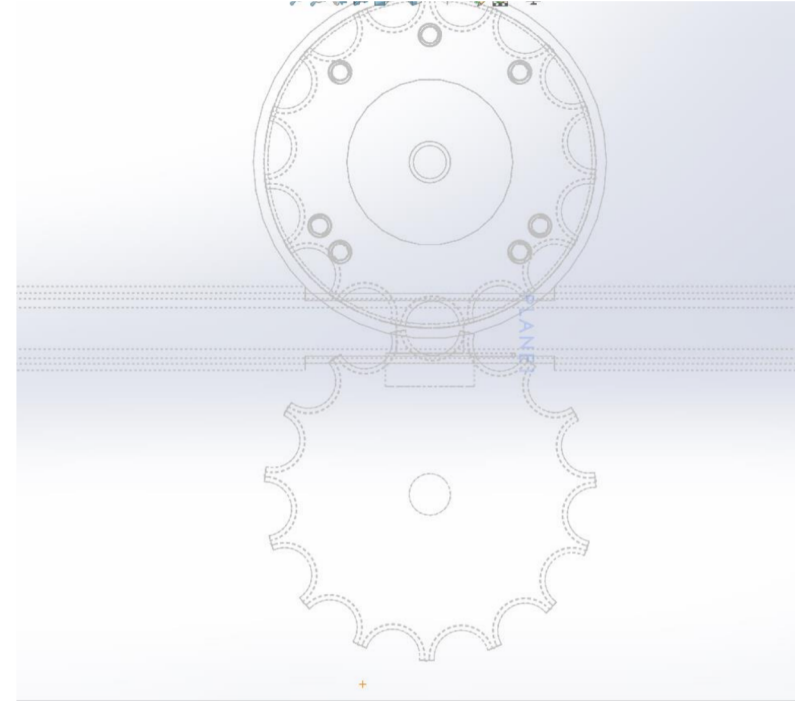
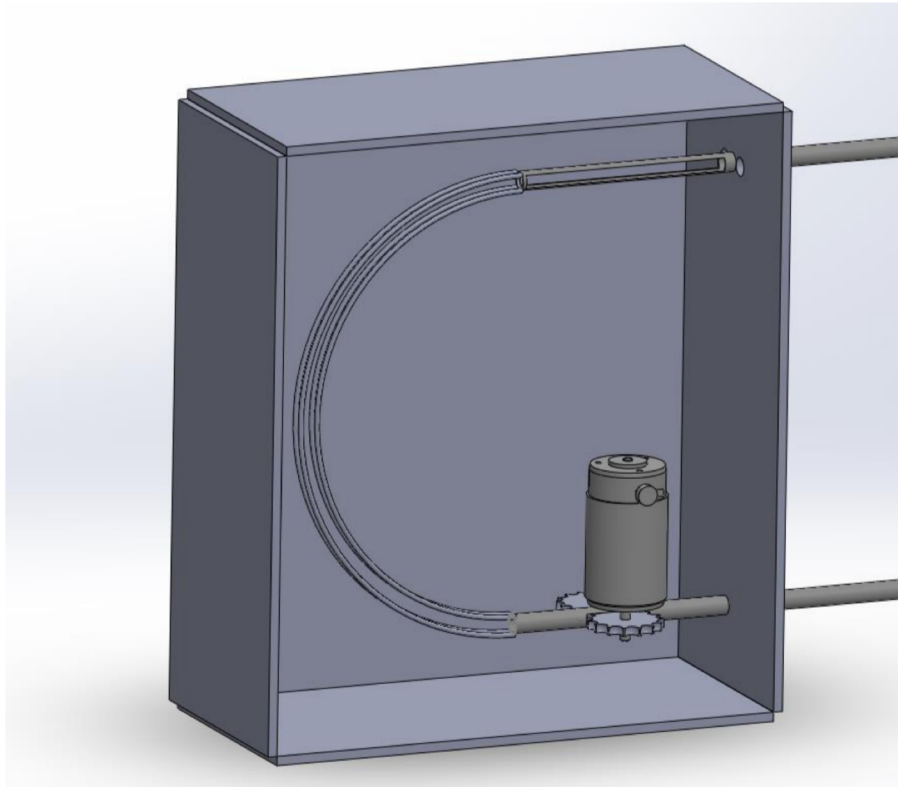
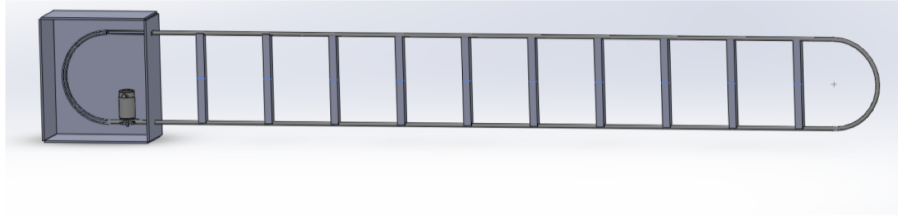
Purchase **NO. 681387** order signed on **09/01/21**

After receiving from the vendor, the prototype will be mechanically tested at Fermilab by the LDRD team

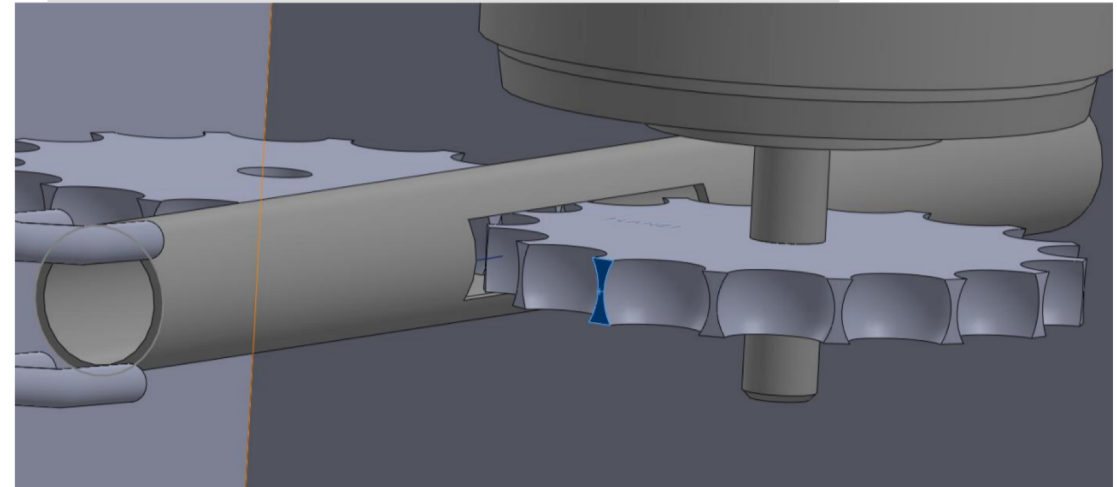
If necessary and time and budget permit, we can consider a prototype with a cooling scheme



Prototyping: progress



Edgar Gomez,
Euclid Techlabs



Summary and future plans

- The conveyor bent target is the optimized design chosen for prototyping

Studies needed

- Collaborate with the vendor on manufacturing the prototype; test it at Fermilab
- Thermal analysis that includes the cooling scheme will be necessary; either two-phase (ammonia) or He cooling (pros and cons)
- Another prototype for thermal analysis with a high energy density may be necessary
- Determine the systematic uncertainties for DPA simulations by comparing MARS15 with FLUKA (resolve discrepancies). For energy deposition the agreement is remarkable (~10%).

Thank you for your attention!